TABLE

GIVING AT INSPECTION

THE

PROPER NET HAULING CAPACITY

IN DAILY SERVICE

OF

ALL WEIGHTS AND TYPES OF LOCOMOTIVES

ON ANY GRADE

From Level to 528 feet per Mile

According to the Actual Records of Practice on Numerous American Railways.

BEING TABLE 170 OF "THE ECONOMIC THEORY OF THE LOCATION OF RAILWAYS," BY A. M. WELLINGTON, M. AM. SOC. C.E.

Correct to nearest ton for 1-4 adhesion and 8 lbs. rolling friction on tangents, even half-tons being dropped. These units are used as those giving results most nearly corresponding with the **actual work** of locomotives in practice. Higher adhesion, up to **1-3** the weight on drivers, is realized in tests, but not in daily work. Lower rolling friction, down to 3 or 4 lbs. per ton, is realized occasionally in the same way, but the engines cannot be loaded correspondingly and do their daily work.

Applicable to either long or short tons, or any other unit, if the weights of engine be supposed to be given in tons of the same kind. The table gives simply, in effect, the **ratio** of net load behind engine to the total adhesion, assumed at ¼ the weight on drivers, for each even ton of adhesion, or each 4 tons on drivers. **Intermediate weights can be interpolated** by inspection. Adding total weight (as assumed) of engine and tender given in the heading gives the gross weight **of engine and train** which an engine of any pattern whatsoever can take up any grade with ¼ adhesion. **For 1-3 adhesion** the gross load will be 33⅓ per cent. greater, and **for 1-5 adhesion** 20 per cent. less. The net load varies slightly with the pattern of engine. **For tank engines** having any given weight on drivers, correct the table by the difference between its actual weight in service, and that assumed for an engine with tender, with same load on drivers, in preparing this table.

The table gives the fair working capacity for locomotives **in every-day service** on *de-facto* grades of the given rate, as evinced by the daily practice of many lines (see Table 138 of the volume above referred to). In **single tests** they will run some 20 per cent. higher; in winter weather, about 10 per cent. lower. Otherwise any considerable excess in reported loads above the following table indicates simply that the grades are not in reality as high as reported, but are probably operated as momentum grades; and any considerable deficiency indicates either carelessness in loading engines to their capacity, or that the profile grades are in effect increased by unreduced curvature or stopping-points on the maximum grade. Thus, a *de-facto* level grade for operating purposes hardly exists in the world; nor can it, except with a very unequal traffic enabling all curves and stations to be on a descending grade without impeding up traffic.

PASSENGER AND HIGH-SPEED TRAIN LOADS

Vary greatly from those of the table. The probable **maximum** resistance on a level at various velocities is given in the following table (the first part of Table 166 of the "Economic Theory of the Location of Railways"). These resistances are probably *one-third too high* for high-speed work under favorable conditions, but approximate very closely to the **ordinary working maximum** for which trains are loaded.

TRAIN RESISTANCE ON A LEVEL AS AFFECTED BY VELOCITY.

Freight Trains. Heavy Consolidation Engine.	Total Weight of Train		Equation of Resistance. Per Short Ton.	Resistance Per Short Ton, for Velocities. Miles Per Hour.				
	Long Tons.	Short Tons.		10	15	20	25	30
Engine only	70	78.4	$4.82 + .0428V^2$	9.10	14.47	21.94	31.59	43 34
" and 10 loaded cars	270	302 4	" $+ .0151V^2$	6.33	8.22	10.86	14.26	18.41
" " 20 " "	470	526.4	" $+ .0109V^2$	5.91	7.17	9.18	11.53	14.63
" " 30 " "	670	750 4	" $+ .00928V^2$	5.75	6.91	8.53	10.62	13.17
" " 40 " "	870	974.4	" $+ .00837V^2$	5.66	6.70	8.17	10.05	12.35
" " 50 " "	1070	1198.4	" $+ .0078V^2$	5.60	6.58	7.94	9.70	11.84
" " 75 " "	1570	1758.4	" $+ .00703V^2$	5.52	6.40	7.63	9.21	11.15
" " 100 " "	2070	2318.4	" $+ .00653V^2$	5.47	6 29	7.33	8.80	10.70

For formulæ of resistances **for trains of flat cars**, *subtract* about .0012 from coefficient of V^2. For resistances and formulæ **per long ton**, *add* 12 per cent.

Passenger Trains. 17 × 24 American Engine.	Total Weight of Train.		Equation of Resistance. Per Short Ton.	Resistance Per Short Ton, for Velocities. Miles Per Hour.							
	Long Tons.	Short Tons.		15	20	25	30	40	50	60	70
Engine only	50	56	$4.82 + .03214V^2$	12 05	17.68	24.91	33 75	56.25	85.18	120.54	162 32
" and 2 cars.	100	112	" $+ .01875V^2$	9.04	12.32	16.54	21.70	34.82	51.70	72.32	96.70
" " 4 "	150	168	" $+ .0143V^2$	8.04	10.54	13.75	17.68	27.69	40.53	56.25	74.82
" " 8 "	250	280	" $+ 0107V^2$	7.23	9.11	11.52	14.46	21.96	31.61	42.39	57.32
" " 12 "	350	392	" $+ .00918V^2$	6.89	8.49	10.56	13.09	19 51	27.78	37.88	49.82
" " 16 "	450	504	" $+ 00833V^2$	6.70	8.16	10 03	12.32	18.15	25.65	34.82	45.65

For resistances and formulæ **per long ton**, *add* 12 per cent.

Weight of cars taken at 25 long tons, 56,000 lbs. each, loaded.

Grades, however steep, affect fast trains very slightly unless long, or with stations on them or at their foot. Ordinary undulations not over 50 or 60 ft. high are virtually eliminated by small fluctuations in high speeds (see "Economic Theory of the Location of Railways," p. 346–375).

The approximate maximum speed which any engine can attain in practice on any long *de-facto* grade at any speed may be determined as follows:

1. Take from the following short table the weight of train to be hauled.
2. Take from the main table the grade that the engine can haul it on at low speed, and subtract the actual grade from it.
3. Find from the following table the speed which increases the virtual grade by the amount of the difference thus obtained.

INCREASE IN VIRTUAL GRADE PER CENT. DUE TO INCREASE IN VELOCITY ABOVE FREIGHT SPEEDS.

(Abstracted from Table 180 of the "Economic Theory of the Location of Railways.")

Kind of Train.	Weight of Cars Tons (2000 lbs.)	Velocities in Miles Per Hour.						
		20	25	30	40	50	60	70
Engine and 2 cars	56	0.22	0.43	0.68	1.34	2.18	3.22	4.43
" " 4 "	112	0 12	0 29	0.48	0.98	1.62	2.41	3.34
" " 8 "	224	0.06	0.18	0.33	0.70	1.18	1.72	2.47
" " 12 "	336	0.02	0.13	0.25	0.58	0.99	1.49	2.09
" " 16 "	448	0.01	0.10	0.22	0.51	0.88	1.34	1.88

Example 1. Eight-car train on 1.5 per cent grade. Heavy American engine can pull 224 tons at slow speed on 1.72 per cent. grade, or 0.22 per cent. above the actual. This corresponds to but little more than a 25-mile per hour maximum, by the above table

Example 2. Four car train, same grade and engine. Engine can pull 112 tons on 3.12 per cent. grade at slow speed; 3.12 — 1.50 = 1.62, corresponding by above table to 50 miles per hour.

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Table 170.

Maximum Working Loads for Locomotives in Daily Service (behind the Tender) on any given *de-facto* Rate of Grade, uncomplicated by Curvature or Fluctuations of Velocity.

Adhesion, ¼. Rolling friction, 8 lbs. Tons of 2000 lbs. (see note, end of table).

☞ *Ratio in fourth column × ¼ wt. on drivers = gross tractive power of any engine, which − wt. eng. and tender = net tractive power, behind tender.*

Tot. weight eng and l'ded tender—tons				52	58	60	64	67	70	75	80	87
Weight engine only—tons				31	37	37	42 38	43	46	51	55	62
Weight on drivers—tons				20	24	28	32	36	40	44	48	52
Tons tractive power (¼ adh.)				**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	**11.**	**12.**	**13.**
Rate of Grade.		Total Resistance, lbs. per net ton.	Ratio of gross w'gt of train to tractive power.	American.		Moguls and 10-wheel.			Consolidations.			Mast'n.
Per 100.	Feet per Mile.			Light. 15 × 24.	Heavy. 18 × 24.	Light 10-wheel. 17 × 24.	H'y 10-wh 19 × 14. Lt. Mog. 17 × 24.	Extra Heavy Mogul. 20 × 24.	Light (P. R.R.). 20 × 24.	Average. 20 × 24.	Heavy. 21 × 24.	Ex. H'y. 21 × 26, or 19 × 30.
Level.	0 00	8.0	250.00	1198	1442	1690	1936	2183	2430	2675	2920	3163
.02	1.056	8.4	238.10	1138	1371	1607	1841	2076	2311	2544	2777	3008
.04	2.112	8.8	227.27	1084	1306	1531	1754	1978	2203	2425	2647	2868
.06	3.168	9.2	217.39	1035	1246	1462	1675	1890	2104	2316	2529	2739
.08	4.224	9.6	208.33	990	1192	1398	1603	1808	2013	2217	2420	2621
.10	5.280	10.0	200.00	948	1142	1340	1536	1733	1930	2125	2320	2513
.12	6.336	10.4	192.31	910	1096	1286	1475	1664	1853	2040	2228	2413
.14	7.392	10.8	185.19	874	1053	1236	1418	1600	1782	1962	2142	2320
.16	8.448	11.2	178.57	841	1013	1190	1365	1540	1716	1889	2063	2235
.18	9.504	11.6	172.41	810	976	1147	1315	1485	1654	1821	1989	2154
.20	10.560	12.0	166.67	781	942	1107	1269	1433	1597	1758	1920	2080
.22	11.616	12.4	161.29	754	910	1069	1226	1385	1543	1699	1855	2010
.24	12.672	12.8	156.25	729	879	1034	1186	1339	1492	1644	1795	1944
.26	13.728	13.2	151.52	706	851	1001	1148	1297	1445	1592	1738	1883
.28	14.784	13.6	147.06	683	824	969	1112	1257	1401	1543	1685	1825
.30	15.840	14.0	142.86	662	799	940	1079	1219	1359	1496	1634	1770
.32	16.896	14.4	138.89	642	775	912	1047	1183	1319	1453	1587	1719
.34	17.952	14.8	135.14	624	753	886	1017	1149	1281	1412	1542	1670
.36	19.008	15.2	131.58	606	731	861	989	1117	1246	1372	1499	1624
.38	20.064	15.6	128.21	589	711	837	962	1087	1212	1335	1459	1580
.40	21.120	16.0	125.00	573	692	815	936	1058	1180	1300	1420	1538
.42	22.176	16.4	121.95	558	674	794	912	1031	1149	1266	1383	1498
.44	23.232	16.8	119.05	543	656	773	888	1004	1120	1235	1349	1461
.46	24.288	17.2	116.28	529	640	754	866	980	1093	1204	1316	1425
.48	25.344	17.6	113.64	516	624	735	845	956	1066	1175	1284	1390
.50	26.400	18.0	111.11	504	609	718	825	933	1041	1147	1253	1357
.52	27.456	18.4	108.70	491	594	701	806	911	1017	1121	1224	1326
.54	28.512	18.8	106.38	480	580	685	787	890	994	1095	1197	1296
.56	29.568	19.2	104.17	469	567	669	769	871	972	1071	1170	1267
.58	30.624	19.6	102.04	458	554	654	752	851	950	1047	1144	1240
.60	31.680	20.0	100.00	448	542	640	736	833	930	1025	1120	1213
.62	32.736	20.4	98.04	438	530	626	720	815	910	1003	1096	1188
.64	33.792	20.8	96.15	429	519	613	705	798	891	983	1074	1163
.66	34.848	21.2	94.34	420	508	600	691	782	873	963	1052	1139
.68	35.904	21.6	92.59	411	498	588	677	766	856	943	1031	1117
.70	36.960	22.0	90.91	403	488	576	663	751	839	925	1011	1095
.72	38.016	22.4	89.29	394	478	565	650	737	823	907	991	1074
.74	39.072	22.8	87.72	387	468	554	638	712	807	890	973	1053
.76	40.128	23.2	86.21	379	459	543	626	709	792	873	955	1033
.78	41.184	23.6	84.75	372	450	533	614	696	777	857	937	1014
.80	42.240	24.0	83.33	365	442	523	603	683	763	842	920	996
.82	43.296	24.4	81.97	358	434	514	592	671	750	827	904	979
.84	44.352	24.8	80.65	351	426	505	581	659	736	812	888	961
.86	45.408	25.2	79.37	345	418	496	571	647	724	798	872	945
.88	46.464	25.6	78.13	339	411	487	561	636	711	784	858	929
.90	47.520	26.0	76.92	333	404	478	551	625	699	771	843	913
.92	48.576	26.4	75.76	327	397	470	542	615	688	758	829	898
.94	49.632	26.8	74.63	321	390	462	533	605	676	746	816	883
.96	50.688	27.2	73.53	316	383	455	524	595	665	734	802	869
.98	51.744	27.6	72.46	310	377	447	516	585	655	722	789	855
1.00	52.800	28.0	71.43	305	371	440	507	576	644	711	777	842
1.02	53.856	28.4	70.42	300	365	433	499	567	634	700	765	828
1.04	54.912	28.8	69.44	295	359	426	492	558	624	689	753	816
1.06	55.968	29.2	68.49	290	353	419	484	549	615	678	742	803
1.08	57.024	29.6	67.57	286	347	413	477	541	606	668	731	791
1.10	58.080	30.0	66.67	281	342	407	469	533	597	658	720	780
1.12	59.136	30.4	65.79	277	337	401	462	525	588	649	709	768
1.14	60.192	30.8	64.94	273	332	395	456	517	579	639	699	757
1.16	61.248	31.2	64.10	268	327	389	449	510	571	630	689	746
1.18	62.304	31.6	63.29	264	322	383	442	503	563	621	679	736
1.20	63.360	32.0	62.50	260	317	377	436	495	555	612	670	725
1.22	64.416	32.4	61.73	257	312	372	430	489	547	604	661	715
1.24	65.472	32.8	60.98	253	308	367	424	482	540	596	652	706
1.26	66.528	33.2	60.24	249	303	362	418	475	532	588	641	696
1.28	67.584	33.6	59.52	246	299	357	412	469	525	580	634	687
1.30	68.640	34.0	58.82	242	295	352	407	462	518	572	626	678
1.32	69.696	34.4	58.14	239	291	347	401	456	511	565	618	669
1.34	70.752	34.8	57.47	235	287	342	396	450	505	557	610	660
1.36	71.808	35.2	56.82	232	283	338	391	444	498	550	602	652
1.38	72.864	35.6	56.18	229	279	333	385	439	492	543	594	643
1.40	73.920	36.0	55.56	226	275	329	380	433	486	536	587	635
1.42	74.976	36.4	54.95	223	272	325	376	428	479	529	579	627
1.44	76.032	36.8	54.35	220	268	320	371	422	473	523	572	620
1.46	77.088	37.2	53.76	217	265	316	366	417	468	516	565	612
1.48	78.144	37.6	53.19	214	261	312	362	412	462	510	558	604
1.50	79.200	38.0	52.63	211	258	308	357	407	456	504	552	597
1.52	80.256	38.4	52.08	208	254	305	353	402	451	498	545	590
1.54	81.312	38.8	51.55	206	251	301	348	397	445	492	539	583
1.56	82.368	39.2	51.02	203	248	297	344	392	440	486	532	576
1.58	83.424	39.6	50.51	201	245	294	340	388	435	481	526	570
1.60	84.480	40.0	50.00	198	242	290	336	383	430	475	520	563
1.62	85.536	40.4	49.50	195	239	286	332	378	425	469	514	556
1.64	86.592	40.8	49.02	193	236	283	328	374	420	464	508	550
1.66	87.648	41.2	48.54	191	233	280	324	370	415	459	502	544
1.68	88.704	41.6	48.08	188	230	277	321	366	411	454	497	538
1.70	89.760	42.0	47.62	186	228	273	317	362	406	449	491	532
1.72	90.816	42.4	47.17	184	225	270	313	358	402	444	486	526
1.74	91.872	42.8	46.73	182	222	267	310	354	397	439	481	520
1.76	92.928	43.2	46.30	179	220	264	306	350	393	434	476	515
1.78	93.984	43.6	45.87	177	217	261	303	346	389	430	470	510
1.80	95.040	44.0	45.45	175	215	258	300	342	384	425	465	504
1.82	96.096	44.4	45.05	173	212	255	296	338	380	421	461	498
1.84	97.152	44.8	44.64	171	210	252	293	335	376	416	456	493
1.86	98.208	45.2	44.25	169	207	250	290	331	372	412	451	488
1.88	99.264	45.6	43.86	167	205	247	287	328	369	407	446	483
1.90	100.320	46.0	43.48	165	203	244	284	324	365	403	442	478
1.92	101.376	46.4	43.10	163	201	242	281	321	361	399	437	473
1.94	102.432	46.8	42.74	162	198	239	278	318	357	395	433	469
1.96	103.488	47.2	42.37	160	196	237	275	314	354	391	428	464
1.98	104.544	47.6	42.02	158	194	234	272	311	350	387	424	459
2.00	105.600	48.0	41.67	156	192	232	269	308	347	383	420	455
2.02	106.656	48.4	41.32	155	190	229	267	305	343	380	416	450
2.04	107.712	48.8	40.98	153	188	227	264	302	340	376	412	446
2.06	108.768	49.2	40.65	151	186	225	261	299	336	372	408	441
2.08	109.824	49.6	40.32	150	184	222	259	296	333	369	404	437
2.10	110.880	50.0	40.00	148	182	220	256	293	330	365	400	433
2.12	111.936	50.4	39.68	146	180	218	253	290	327	361	396	429

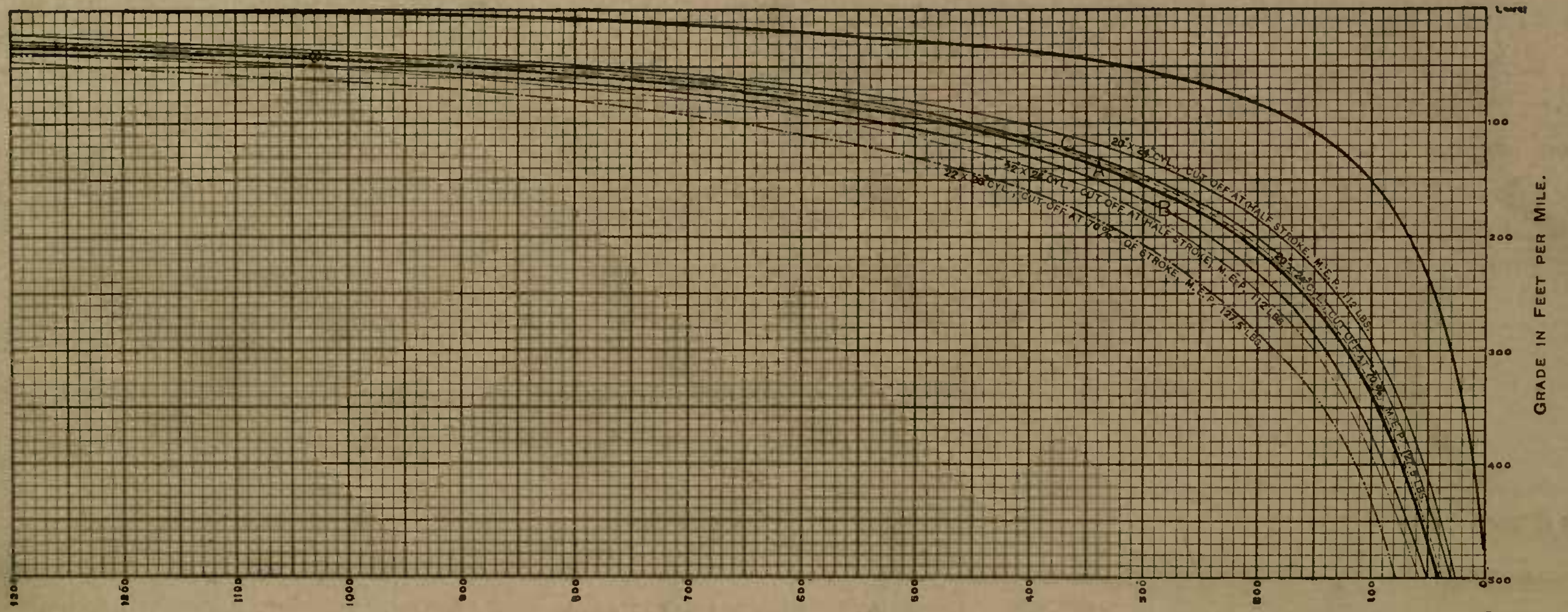
TABLE 170.—*Continued.*

MAXIMUM WORKING LOADS FOR LOCOMOTIVES IN DAILY SERVICE (BEHIND THE TENDER) ON ANY GIVEN *de-facto* RATE OF GRADE, UNCOMPLICATED BY CURVATURE OR FLUCTUATIONS OF VELOCITY.

Adhesion, ¼. Rolling friction, 8 lbs. Tons of 2000 lbs. (see note, end of table).

☞ *Ratio in fourth column × ¼ wt. on drivers = gross tractive power of any engine, which − wt. eng. and tender = net tractive power, behind tender.*

Tot. weight eng. and l'ded tender—tons				52	58	60	64	67	70	75	80	87
Weight engine only—tons				31	37	37	42 38	43	46	51	55	62
Weight on drivers—tons				20	24	28	32	36	40	44	48	52
Tons tractive power (¼ adh.)				**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	**11.**	**12.**	**13.**
Rate of Grade.		Total Resistance, lbs. per net ton.	Ratio of gross w'gt of train to tractive power.	American.		Moguls and 10-wheel.			Consolidations			Mast'n.
Per 100.	Feet per Mile.			Light. 15 × 24.	Heavy. 18 × 24.	Light 10-wheel. 17 × 24.	H'y 10-wh 19 × 14. Lt. Mog. 17 × 24.	Extra Heavy Mogul. 20 × 24.	Light (P. R. R.). 20 × 24.	Average. 20 × 24.	Heavy. 21 × 24.	Ex. H'y, 21 × 26, or 19 × 30.
2.14	112.992	50.8	39.37	145	178	216	251	287	324	358	392	425
2.16	114.048	51.2	39.06	143	176	213	248	285	321	355	389	421
2.18	115.104	51.6	38.76	142	175	211	246	282	318	351	385	417
2.20	116.160	52.0	38.46	140	173	209	244	279	315	348	382	413
2.22	117.216	52.4	38.17	139	171	207	241	277	312	345	378	409
2.24	118.272	52.8	37.88	137	169	205	239	274	309	342	375	405
2.26	119.328	53.2	37.59	136	168	203	237	271	306	338	371	402
2.28	120.384	53.6	37.31	135	166	201	234	269	303	335	368	398
2.30	121.440	54.0	37.04	133	164	199	232	266	300	332	364	395
2.32	122.496	54.4	36.76	132	163	197	230	264	298	329	361	391
2.34	123.552	54.8	36.50	130	161	195	228	261	295	326	358	387
2.36	124.608	55.2	36.23	129	159	194	226	259	292	324	355	384
2.38	125.664	55.6	35.97	128	158	192	224	257	290	321	352	381
2.40	126.720	56.0	35.71	127	156	190	222	254	287	318	349	377
2.42	127.776	56.4	35.46	125	155	188	220	252	285	315	346	374
2.44	128.832	56.8	35.21	124	153	186	218	250	282	312	343	371
2.46	129.888	57.2	34.97	123	152	185	216	248	280	310	340	368
2.48	130.944	57.6	34.72	122	150	183	214	245	277	307	337	364
2.50	132.000	58.0	34.48	120	149	181	212	243	275	304	334	361
2.52	133.056	58.4	34.25	119	147	180	210	241	272	302	331	358
2.54	134.112	58.8	34.01	118	146	178	208	239	270	299	328	355
2.56	135.168	59.2	33.78	117	145	176	206	237	268	297	325	352
2.58	136.224	59.6	33.56	116	143	175	204	235	266	294	323	349
2.60	137.280	60.0	33.33	115	142	173	203	233	263	292	320	346
2.62	138.336	60.4	33.11	114	141	172	201	231	261	289	317	343
2.64	139.392	60.8	32.89	112	139	170	199	229	259	287	315	341
2.66	140.448	61.2	32.68	111	138	169	197	227	257	284	312	338
2.68	141.504	61.6	32.47	110	137	167	196	225	255	282	310	335
2.70	142.560	62.0	32.26	109	136	166	194	223	253	280	307	332
2.72	143.616	62.4	32.05	108	134	164	192	221	250	278	305	330
2.74	144.672	62.8	31.85	107	133	163	191	220	248	275	302	327
2.76	145.728	63.2	31.65	106	132	162	189	218	246	273	300	324
2.78	146.784	63.6	31.45	105	131	160	188	216	244	271	297	322
2.80	147.840	64.0	31.25	104	129	159	186	214	242	269	295	319
2.82	148.896	64.4	31.06	103	128	157	184	213	241	267	293	317
2.84	149.952	64.8	30.86	102	127	156	183	211	239	264	290	314
2.86	151.008	65.2	30.67	101	126	155	181	209	237	262	288	312
2.88	152.064	65.6	30.49	100	125	153	180	207	235	260	286	309
2.90	153.120	66.0	30.30	99	124	152	178	206	233	258	284	307
2.92	154.176	66.4	30.12	99	123	151	177	204	231	256	281	305
2.94	155.232	66.8	29.94	98	122	150	176	202	229	254	279	302
2.96	156.288	67.2	29.76	97	121	148	174	201	228	252	277	300
2.98	157.344	67.6	29.59	96	120	147	173	199	226	250	275	298
3.00	158.400	68.0	29.41	95	118	146	171	198	224	249	273	295
3.05	161.04	69.0	28.99	93	116	143	168	194	220	244	268	290
3.10	163.68	70.0	28.57	91	113	140	165	190	216	239	263	284
3.15	166.32	71.0	28.17	89	111	137	161	187	212	235	258	279
3.20	168.96	72.0	27.78	87	109	134	158	183	208	231	253	274
3.25	171.60	73.0	27.40	85	106	132	155	180	204	226	249	269
3.30	174.24	74.0	27.03	83	104	129	152	176	200	222	244	264
3.35	176.88	75.0	26.67	81	102	127	149	173	197	218	240	260
3.40	179.52	76.0	26.32	80	100	124	147	170	193	215	236	255
3.45	182.16	77.0	25.97	78	98	122	144	167	190	211	232	251
3.50	184.80	78.0	25.64	76	96	119	141	164	186	207	228	246
3.55	187.44	79.0	25.32	75	94	117	139	161	183	204	224	242
3.60	190.08	80.0	25.00	73	92	115	136	158	180	200	220	238
3.65	192.72	81.0	24.69	71	90	113	134	155	177	197	216	234
3.70	195.36	82.0	24.39	70	88	111	131	153	174	193	213	230
3.75	198.00	83.0	24.10	68	87	109	129	150	171	190	209	226
3.80	200.64	84.0	23.81	67	85	107	126	147	168	187	206	223
3.85	203.28	85.0	23.53	66	83	105	124	145	165	184	202	219
3.90	205.92	86.0	23.26	64	82	103	122	142	163	181	199	215
3.95	208.56	87.0	22.99	63	80	101	120	140	160	178	196	212
4.00	211.20	88.0	22.73	62	78	99	118	138	157	175	193	208
4.05	213.84	89.0	22.47	60	77	97	116	135	155	172	190	205
4.10	216.48	90.0	22.22	59	75	96	114	133	152	169	187	202
4.15	219.12	91.0	21.98	58	74	94	112	131	150	167	184	199
4.20	221.76	92.0	21.74	57	72	92	110	129	147	164	181	196
4.25	224.40	93.0	21.51	56	71	91	108	127	145	162	178	193
4.30	227.04	94.0	21.28	54	70	89	106	125	143	159	175	190
4.35	229.68	95.0	21.05	53	68	87	104	122	140	157	173	187
4.40	232.32	96.0	20.83	52	67	86	103	120	138	154	170	184
4.45	234.96	97.0	20.62	51	66	84	101	119	136	152	167	181
4.50	237.60	98.0	20.41	50	64	83	99	117	134	150	165	178
4.55	240.24	99.0	20.20	49	63	81	98	115	132	147	162	175
4.60	242.88	100.0	20.00	48	62	80	96	113	130	145	160	173
4.65	245.52	101.0	19.80	47	61	79	94	111	128	143	158	170
4.70	248.16	102.0	19.61	46	60	77	93	109	126	141	155	168
4.75	250.80	103.0	19.42	45	59	76	91	108	124	139	153	165
4.80	253.44	104.0	19.23	44	57	75	90	106	122	137	151	163
4.85	256.08	105.0	19.05	43	56	73	88	104	120	135	149	161
4.90	258.72	106.0	18.87	42	55	72	87	103	119	133	146	158
4.95	261.36	107.0	18.69	41	54	71	86	101	117	131	144	156
5.00	264.00	108.0	18.52	41	53	70	84	100	115	129	142	154
5.2	274.56	112.0	17.86	37	49	65	79	94	109	121	134	145
5.4	285.12	116.0	17.24	34	45	61	74	88	102	115	127	137
5.6	295.68	120.0	16.67	31	42	57	69	83	97	108	120	130
5.8	306.24	124.0	16.13	29	39	53	65	78	91	102	114	123
6.0	316.80	128.0	15.62	26	36	49	61	74	86	97	107	116
6.2	327.36	132.0	15.15	24	33	46	57	69	81	92	102	110
6.4	337.92	136.0	14.71	22	30	43	54	65	77	87	97	104
6.6	348.48	140.0	14.29	19	28	40	50	62	73	82	91	99
6.8	359.04	144.0	13.89	17	25	37	47	58	69	78	87	94
7.00	369.60	148.0	13.51	16	23	35	44	55	65	74	82	89
7.2	380.16	152.0	13.16	14	21	32	41	51	62	70	78	84
7.4	390.72	156.0	12.82	12	19	30	39	48	58	66	74	80
7.6	401.28	160.0	12.50	10	17	27	36	45	55	62	70	75
7.8	411.84	164.0	12.20	9	15	25	34	44	52	59	66	72
8.00	422.40	168.0	11.90	7	13	23	31	40	49	56	63	70
8.2	432.96	172.0	11.63	6	12	21	29	38	46	53	60	64
8.4	443.52	176.0	11.36	5	10	20	27	35	44	50	56	61
8.6	454.08	180.0	11.11	4	9	18	25	33	41	47	53	57
8.8	464.64	184.0	10.87	2	7	16	23	31	39	45	50	54
9.00	475.20	188.0	10.64	1	6	14	21	29	36	42	48	51
9.2	485.76	192.0	10.42	0	5	13	19	27	34	40	45	48
9.4	496.32	196.0	10.20	....	3	11	18	25	32	37	42	46
9.6	506.88	200.0	10.00	....	2	10	16	23	30	35	40	43
9.8	517.44	204.0	9.80	....	1	9	14	21	28	33	38	40
10.00	528.00	208.0	9.62	....	0	7	13	20	26	31	35	38



NET TRAIN-LOAD IN TONS BEHIND TENDER.

Diagram Illustrating the Rate of Variation in the Hauling Power of Engines on Various Grades, and the Ratio of Tractive to Cylinder Power.

NOTES TO DIAGRAM.—This diagram, which constitutes Fig. 169 of "The Economic Theory of the Location of Railways," is reduced from one prepared by Mr. G. W. CUSHING, Supt. of Motive Power, Northern Pacific Ry., with certain lines added. It is somewhat confusing on first examination, from the fact that it is not constructed according to established geometric methods, with a common origin for the two co-ordinate axes at their intersection **O**. It can best be studied by regarding the end of the diagram to the right, as the horizontal axis (axis of *x*), and regarding the curves as indicating the increase of net load from progressive diminutions of grade resistance. It is explained further in the discussion of "The Hauling Power of Engines."

Regarding this end of the diagram as the base-line (or "axis of *x*") as explained beneath the title to it:

1. *The lower heavy line* represents the progressive increase of train-load (behind tender) as the grade is reduced, for the *lightest American engine* given in Table 170, which begins at **O** at a grade of 480 ft. per mile, and ends at 1198 tons on a level, just within the limits of the diagram.

2. *The upper heavy line*, marked **A**, represents the same thing for the *heaviest Mastodon engine* given in Table 170 within, so nearly that it is not in error by more than its own width at any point.

Similar lines for all the other nine engines whose tractive capacities are given in Table 170 within, would fall between these two lines at approximately regular intervals. It has not seemed necessary to plot them.

The remaining lines of the diagram give the cylinder and adhesion tractive powers separately for the three different engines below detailed, as computed by Mr. G. W. CUSHING, Supt. M. P. No. Pac. Ry., on the following assumptions:

Rolling friction, 6½ lbs. per ton in place of 8 lbs. per ton, as for the table within.

Ratio of adhesion, ¼, as in the table within.

The difference in the rolling friction makes the train-loads slightly greater than those given in Table 170, especially as a level is approached, but makes no great difference on the higher grades. The three engines are as follows:

ENGINE.	Cylinders.	Drivers	Trac. P'r in Lbs. per Lb. of Effective Pressure.	No. of Drivers	WEIGHTS. On Drivers	Total Engine.	Tender Loaded	Total.
	Inches.	Inches.						
A	22 x 26	49	256.8	8	100,000	112,000	65,000	177,000
B	22 x 26	49	256.8	10	110,000	112,000	65 000	177,000
C	20 x 24	49	196	8	96,000	108,000	65,000	173,000